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Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 02078378.3
Demande no:

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Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Full color electrochromic display with stacked in cell monochromic electrochromes

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G09G/

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Full color electrochromic display with stacked in cell monochromic electrochromes

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15. 08. 2002

(41)

BACKGROUND OF THE INVENTION

Field of the Invention

The present patent application relates to the field of electrochromic display devices, and particularly to an apparatus for providing full color operation to such display devices and a drive method therefor. More specifically, the present patent application relates to an efficient system for providing full color operation to each pixel cell of electrochromic display devices.

Description of the Related Art

Recently electrochromic display devices have been studied as candidates for electronic paper type of displays. However, the slow switching speed and high power consumption of the today commercially available electrochromic display technologies do not meet the needs of the display market. Lately the trend has been towards the use of nano-materials, such as chemically modified nano-structured mesoporous films, for improving performance. Use of such materials has shown promising results. However, one of the remaining key issues with respect to electrochromic displays is the generation of color.

One prior art approach suggest selective color generation using a four layer light filter which comprises five transparent plates each having electrolytes formed on their facing surfaces. The plates being glass or plastic plates, coated with tin oxide or thin metallic transparent conductors on their facing surfaces. Disposed on one of the electrodes of each pair of facing electrodes is a thin layer (0.01 μm to 0.1 μm) of an electrochromic conducting polymer. Although four layers have been described, it is suggested that two or more layers may be used in any combination of voltages to allow the transmission of different colors and tints through the panel. A system of this type is disclosed in US 4 749 260.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved apparatus for providing full color to an electrochromic display appliance.

This object is achieved by the apparatus according to the invention as specified in claim 1.

A further object of the invention is to provide an improved drive method for providing full color to an electrochromic display appliance.

This object is achieved by the method according to the invention as specified in claim 8.

Further advantageous embodiments of the invention are specified in the dependent claims.

Still other objects and features of the present invention will become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for purposes of illustration and not as a definition of the limits of the invention, for which reference should be made to the appended claims. It should be further understood that the drawings are not necessarily drawn to scale and that, unless otherwise indicated, they are merely intended to conceptually illustrate the structures and procedures described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, wherein like reference characters denote similar elements throughout the several views:

Fig. 1 discloses a schematic cross section view of a pixel of a display device according to a first embodiment of the invention;

Fig. 2 discloses a schematic cross section view of the pixel of a display device according to a second embodiment of the invention;

Fig. 3 discloses a schematic cross section view of the pixel of a display device according to a third embodiment of the invention;

Fig. 4 discloses a general example of the structure of a conventional active-matrix display device;

Fig. 5 discloses a simplified single line drive circuit for an electrochromic pixel in accordance with the present invention;

Fig. 6 discloses a simplified two line drive circuit for an electrochromic pixel in accordance with the present invention;

Fig. 7 discloses a simplified single power line drive circuit for a colored electrochromic pixel with multiple addressing rows; and

Fig. 8 discloses a simplified drive circuit for a colored electrochromic pixel with multiple data columns and two power lines per pixel.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

Fig. 1 shows a schematic cross section view of a pixel 1 of an electrochromic display according to a first embodiment. Each pixel of the electrochromic display is independently addressable and can be separated from other pixels either electrically or physically, in order to avoid cross-talk between pixels. The pixel 1 comprises: a first substrate 2, which preferably is transparent and made out of a material such as a glass or plastic plate; a conductive counter-electrode 3 associated with said first substrate 2; a second substrate 4, which can be reflective or transparent; a stack of electrochromic-layers 5a, 5b, 5c associated with said second substrate 4; a transparent electrolytic material 6 disposed between said counter-electrode 3 and said stack of electrochromic-layers 5a, 5b, 5c and in contact with said counter-electrode 3 and the adjacent electrochromic-layer 5c in said stack of electrochromic-layers 5a, 5b, 5c. The electrochromic-layers 5a, 5b, 5c are independently addressable for switching operation. Each electrochromic-layer 5a, 5b, 5c can be reversibly switched between a transparent and a colored state by applying appropriate positive and negative voltages across the pixel cell. Full color operation is preferably achieved using the well-known subtractive color approach. According to the invention this is achieved through the stacking and independent addressing of three electrochromic-layers 5a, 5b, 5c in the pixel cell. Preferably, as shown in figure 1, three monochromic electrochromic-layers are used, these three electrochromic-layers are preferably Cyan, Magenta and Yellow (CMY) which enables achievement of all colors in a reflective display, including white and black, although as an alternative, also a Red, Green, Blue (RGB) color approach may be used, however this is expected to result in reduced optical performance in the generation of complementary colors. The combination of the complementary (or primary) colors in combination with control of the electron flow towards the electrochromic-layer (gray-scale control) enables the generation of full color operation. As the electrochromic-layers 5a, 5b, 5c in the stack need to be independently addressed, it is required to physically separate the electrochromic-layers 5a, 5b, 5c with respect to each other in order to prevent cross-talk. This is preferably achieved using electrolyte layers 7 between the electrochromic-layers 5a, 5b, 5c, which electrolyte layers 7 are arranged to communicate with the electrolytic material 6 such that a direct ionic path exist there between, as will be described in more detail in the following. In order to ensure sufficient mechanical support, a solid-state like electrolyte, such as a polymeric

electrolyte, is preferred. Moreover, the electrolyte is an essential part of the display cell, as it contains ions for charge compensation in the electrochemical oxidation or reduction reaction of the electrochromic-layers. The electrolyte layers 7 also facilitate rapid transport of counter-ions which promotes a rapid response of the electrochromic reaction. In an alternative embodiment, the separating layers 7 between the stacked electrochromic-layers 5a, 5b, 5c may be composed of a porous insulator, which is filled with an electrolyte. In accordance with the embodiment of figure 1 electrodes contacting the electrochromic-layers are required at one or multiple sides of the pixel, in figure 1 illustrated as Indium Tin Oxide (ITO) tracks 17 on the substrate 4 connected to the power lines 8a, 8b, 8c, and to which ITO tracks 17 the electrochromic-layers are brought into connection, if required through so-called "via" kind of connections. In such a configuration, electron transport occurs laterally across the pixel in stead of the conventional electron transport in the depth direction. As the lateral dimension is much larger than the depth dimension, electrochromic-layers 5a, 5b, 5c are required which provide a rapid transport of electrons. In such a case, the electrochromic-layer itself serves as an electrode. A known class of electrochromic materials with these properties are conductive polymers. These polymers commonly can be electrochemically switched from a high conducting to a lower conducting state in which a simultaneous difference in optical response occurs. A further advantage of the electrochromic class of conducting polymers is their process-ability and pattern-ability in ink-jet printing technologies or lithographic technologies. In order to prevent cross-talk in an active-matrix (AM) display, there are no pixel walls required between adjacent pixels. It is possible to pixelate (pattern) the electrochromic-layers in order to prevent direct electron transport from one pixel to the next. A small space between the pixels is sufficient in such a case. The capacity of the counter-electrode 3 should be sufficient to provide an electrochemical counter reaction which supports all electrochromic-layers 5a, 5b, 5c in the stack. The capacity of the counter-electrode 3 should preferably be such that the redox state of the counter-electrode is not significantly altered when the various electrochromic-layers are addressed with respect to said counter-electrode. Further, it is also possible to pixelate the counter-electrode 3. Each pixel of the display device can have its own counter-electrode 3, but there might also be one common counter-electrode plane, i.e. the counter-electrodes 3 of each pixel of the display device are connected to form one common counter-electrode. A line 16 for connection of the counter-electrode to a display drive circuit is shown in figure 1, which line 16 in the case of the counter-electrode being common to all pixels need only connect once for the whole display device. A hole or gap 9 within the pixel (an electrolyte via, e.g. at the side(s) of the

pixel) is required to ensure overall charge neutrality of the pixel cell and to facilitate ionic contact with the associated counter-electrode. When the display is used for transmissive operation, e.g. using a backlight, the entire pixel cell will be transparent when all the electrochromic-layers 5a, 5b, 5c are in transparent states. For reflective operation of the display, it is required that a reflector, preferably diffuse, is added to the substrate side of the pixel cell facing away from the viewer, which might be the first substrate 2 or the second substrate 4. The horizontal broken lines of figure 1 illustrates that the first substrate 2, the counter-electrode 3 as well as the second substrate 4 can be much larger and comprise additional pixels cells. The vertical broken lines are only used to illustrate the borders of the pixel cell 1 described.

Fig. 2 illustrates an alternative embodiment where the pixel 1 in addition to what has been described with reference to figure 1 comprises an independently addressable working electrode 10a, e.g. composed of conventionally used transparent Indium Tin Oxide (ITO), arranged between the second substrate 4 and the electrochromic-layer 5a adjacent to the second substrate 4 in the stack of electrochromic-layers 5a, 5b, 5c. This electrochromic-layer 5a in this case is preferably deposited on the electrode 10a and may therefore be switched conventionally in the depth direction rather than laterally (as described above). Alternatively this electrode 10a may be porous, such as nano-crystalline TiO_2, to further increase counter-ion diffusion, or promote electron transfer to an absorbed electrochromic species.

Fig. 3 illustrates a further alternative embodiment where the pixel 1 in addition to what has been described with reference to figure 1 comprises electrode layers 10a, 10b, 10c which are associated with and support the electrochromic-layers 5a, 5b, 5c. Each respective electrode layer 10a, 10b, 10c can be arranged, as shown in figure 3, such that its associated electrochromic-layer 5a, 5b, 5c is situated between said electrode layer and the counter-electrode 3, but it is also possible to arrange the electrode layers 10a, 10b, 10c between its associated electrochromic-layer and the counter-electrode 3. The electrode supporting one electrochromic-layer is separated from another electrochromic-layer by a mechanically supporting electrolyte 7, such as a solid-state or gel like electrolyte, which can be a polymer electrolyte. The electrode layers 10b, 10c are brought into connection with the corresponding ITO tracks 17 through so-called "via" kind of connections. A configuration in accordance with this embodiment adds to complexity and reflection losses but provides an opportunity to switch the electrochromic-layers 5a, 5b, 5c conventionally in the depth direction and also enables the use of a larger span of electrochromic materials. Also these

supporting electrodes 10a, 10b, 10c may be porous, such as nano-crystalline TiO_2, to further facilitate counter-ion diffusion or promote electron transfer to an absorbed electrochromic species.

Referring to figure 4, a general example of the structure of a conventional active-matrix display device is presented. The active-matrix display device comprises a panel having a row and column matrix array of regularly spaced pixels, denoted by the blocks 1, carried on a substrate 4, each comprising an electrochromic display element and an associated driving device controlling the current flow through the display element, and which are located at the intersections between crossing sets of row selection and column data address conductors, or lines, 12 and 11 also carried on the substrate. Only a few pixels 1 are shown for simplicity. The pixels 1 are addressed via the sets of address conductors by a peripheral drive circuit having outputs connected to the panel and comprising a row, scanning, driver circuit 18 generating scanning signals supplied to the row conductors 12 in sequence and a column, data, driver circuit 19 generating data signals supplied to the column conductors 11 and defining the display outputs from the individual pixel display elements, and a timing control unit 20 for controlling the operation of the circuits 18 and 19.

Each row of pixels is addressed in turn by means of a selection signal applied by the circuit 18 to the relevant row conductor 12 so as to load the pixels of the row with respective drive signals according to the respective data signals supplied in parallel by the circuit 19 to the column conductors 11. As each row is addressed, the data signals are supplied by the circuit 19 in appropriate synchronization.

Fig. 5 illustrates a single power line drive circuit for an electrochromic-layer 5 or a working electrode 10 associated with said electrochromic-layer 5 of an electrochromic pixel 1 which e.g. can be arranged in one of the blocks 1 of the active-matrix display of figure 1. Each pixel drive circuit includes a switching transistor 13, a driving transistor 14, a capacitor 15, and an electrochromic-layer 5, possibly associated with a working electrode 10. The switching transistor 13 and the driving transistor 14 are preferably Thin Film Transistors (TFTs). A gate of the switching transistor 13 is connected to a row select electrode line 12 and a source of the switching transistor 13 is connected to a column data electrode line 11. A drain of the switching transistor 13 is connected to a gate of the driving transistor 14. A source of the driving transistor 14 is connected to a power line 8, and a drain of the driving transistor 14 is connected to the electrochromic-layer 5 or the working electrode 10 associated with said electrochromic-layer 5. The drive circuit is controllable via the column data input 11 and the row select input 12 providing control of application of power line

voltage to an electrochromic-layer 5 or the working electrode 10 associated with said electrochromic-layer 5 of said pixel 1. Through use of the simple pixel circuit of figure 5 an electrochromic-layer 5 of the pixel 1 can be colored and bleached. The operation is as follows: a power line 8 is set to a bleaching voltage; the display is addressed with two voltages, where a high voltage causes the drive transistor 14 to become conducting and a low voltage stops the transistor 14 conducting; a reset operation is performed through addressing all pixels 1 with high voltage, whereby the corresponding electrochromic-layers 5 of all pixels 1 are bleached (pixels which are already bleached will do nothing at this stage). The storage capacitor 15 ensures that the drive transistor 14 remains conducting during a hold period. All pixels 1 are addressed with a low voltage, which turns the drive transistor 14 off. The power line voltage is switched to a coloring voltage. Those pixels 1 the electrochromic-layers 5 of which require coloring are addressed to a high voltage. The drive transistor 14 becomes conducting and coloration begins. The storage capacitor 15 ensures once again that the drive transistor 14 remains conducting during the hold period. When the electrochromic-layer 5 of the pixel is sufficiently colored, the electrochromic-layer 5 of the pixel 1 is disconnected from the power line 8 by addressing the pixel 1 with a low voltage from data input 11. When a new image is fully written, the power line 8 can be powered down. In this embodiment, the gray-level ("intensity") of the color will be defined by the integral amount of charge passing into the electrochromic-layer 5 and hence by the time in which the electrochromic-layer 5 or the working electrode 10 associated with said electrochromic-layer 5 of the pixel 1 is connected to the power line 8.

Fig. 6 illustrates a more complex pixel circuit with two power lines 8a1, 8a2, whereby an electrochromic-layer 5a can be colored and bleached. The drive circuit is controllable via two column data inputs 11a1, 11a2 and two row select inputs 12a1, 12a2 providing control of application of power line voltage to an electrochromic-layer 5a or the working electrode 10a associated with said electrochromic-layer 5a of said pixel 1. The operation of the pixel circuit is as follows: The power lines 8a1, 8a2 are set to a bleaching voltage and a coloration voltage respectively. The display is addressed with two voltages, where a high voltage causes a drive transistor 14a1, 14a2 to become conducting and a low voltage stops the drive transistor 14a1, 14a2 conducting. Column data 11a1 is used to select pixels 1 the electrochromic-layer 5a of which require bleaching. Column data 11a2 is used to select pixels 1 the electrochromic-layer 5a of which require coloring. Those pixels 1 the electrochromic-layers 5a of which require coloring or bleaching are addressed to a high voltage. The drive transistor 14a1, 14a2 becomes conducting and bleaching or coloration

begins. The storage capacitor 15 ensures that the drive transistor 14a1, 14a2 remains conducting during the hold period. When the electrochromic-layer 5a of the pixel 1 is sufficiently colored or bleached the electrochromic-layer 5a or the working electrode 10a associated with said electrochromic-layer 5a is disconnected from the power line 8a1, 8a2 by addressing the pixel 1 with a low voltage from data inputs 11a1, 11a2. When a new image is fully written, the power lines 8a1, 8a2 can be powered down. Again, in this embodiment, the gray-level ("intensity") of the color will be defined by the integral amount of charge passing into the electrochromic-layer 5a and hence by the time in which the electrochromic-layer 5a or the working electrode 10a associated with said electrochromic-layer 5a is connected to the power line 8a1, 8a2. As in general no "reset" will be used, it will be necessary to know the previous state of the electrochromic-layer 5a before supplying the correct amount of charge (or discharge) to reach the new gray-level. This requires a signal processing approach, where the previous gray-level is stored in a frame memory, the new gray-level compared with the previous gray-level and the required charge determined (via look-up-table or analytical function). This will be supplied to the pixel 1 as the pixel data via data inputs 11a1, 11a2.

In Fig. 7 an embodiment of the present invention is rendered which could drive a color pixel 1 with three independently switchable electrochromic-layers 5a, 5b, 5c. The electrochromic-layers 5a, 5b, 5c or the working electrodes 10a, 10b, 10c associated with said electrochromic-layers 5a, 5b, 5c are individually driven using the pixel circuit with single power line according to figure 5. The pixel data is supplied in sequential manner to the three electrochromic-layers 5a, 5b, 5c or the working electrodes 10a, 10b, 10c associated with said electrochromic-layers 5a, 5b, 5c by addressing the three rows in consecutive line periods (as illustrated by the row select signals 12a, 12b, 12c at the left hand side of figure 7). The operation of the individual pixels is as discussed for the embodiment according to figure 5. In an alternative embodiment the two power line circuit of figure 6 could be implemented to drive the individual pixels. In this situation, every pixel would be provided with two row lines 12a1, 12a2, 12b1, 12b2, 12c1, 12c2 to connect the electrochromic-layers 5a, 5b, 5c or the working electrodes 10a, 10b, 10c associated with said electrochromic-layers 5a, 5b, 5c to either of the power lines 8a1, 8a2, 8b1, 8b2, 8c1, 8c2. In the most general case, such a pixel would therefore be provided with six power lines. If electrochromic materials could be found which operate at the same voltages (either for bleaching or coloration) the number of power lines could be reduced by sharing power lines between two or more electrochromic-layers or the working electrodes associated with said electrochromic-layers. This would save space in

the pixel (increase aperture) and reduce complexity and is therefore a preferred embodiment of the present invention.

Fig. 8 illustrates an embodiment of a drive circuit for a colored electrochromic pixel 1 with multiple data columns 11a1, 11a2, 11b1, 11b2 and two power lines 8a1, 8a2, 8b1, 8b2 per pixel 1, which could drive a color pixel 1 with two independently switchable electrochromic-layers 5a, 5b (extension to three layers being trivial, but is not shown for clarity reasons). Here, the electrochromic-layers 5a, 5b or the working electrodes 10a, 10b associated with said electrochromic-layers 5a, 5b are individually driven using the pixel circuit with two power lines (figure 6). The pixel data is supplied in parallel manner to the two electrochromic-layers 5a, 5b or the working electrodes 10a, 10b associated with said electrochromic-layers 5a, 5b by addressing the four data columns 11a1, 11a2, 11b1, 11b2 in the same line period. The operation of the individual pixels is as discussed with respect to the embodiment of figure 6. In an alternative embodiment the single power line circuit of figure 5 could be implemented to drive the individual pixels. In this situation, every pixel would be provided with only one row line 12, and only a single column data line 11 per electrochromic-layer would be required. Operation (according to the embodiment of figure 5) would again require that all the pixels are first reset (i.e. bleached) before the new image is written to the pixels. If electrochromic materials could be found which operate at the same voltages (either for bleaching or coloration) the number of power lines could be reduced by sharing power lines 8 between two or more electrochromic-layers 5 or the working electrodes 10 associated with said electrochromic-layers 5. This will save space in the pixel (increase aperture) and reduce complexity and is therefore a preferred embodiment of the invention.

A drive method for operating a pixel 1 of a display device according to any one of the above described embodiments, comprises the steps of: providing at least one power line 8 which is selectively connectable to an electrochromic-layer 5 or to a working electrode 10 associated with said electrochromic-layer 5; selectively providing to said power line 8 a bleaching or coloring voltage; addressing the electrochromic-layer 5 or the working electrode 10 associated with said electrochromic-layer 5 which is to be bleached or colored; connecting said power line 8 to said electrochromic-layer 5 or said working electrode 10 associated with said electrochromic-layer 5 addressed; retaining the connection of said power line 8 to said electrochromic-layer 5 or said working electrode 10 associated with said electrochromic-layer 5 addressed during a hold period; disconnecting said power line 8 from said electrochromic-layer 5 or said working electrode 10 associated with said electrochromic-layer 5 addressed.

In a further embodiment the drive method is applied to the additional electrochromic-layers 5 of the pixel 1 through addressing the additional electrochromic-layers 5 or the working electrodes 10 associated with said additional electrochromic-layers 5 is in a sequential manner in consecutive line periods.

In a yet further embodiment the drive method is applied to the additional electrochromic-layers 5 of the pixel 1 through addressing the additional electrochromic-layers 5 or the working electrodes 10 associated with said additional electrochromic-layers 5 in a parallel manner in the same line period.

As illustrated by the above, a full color active-matrix electrochromic display which enables the generation of full color operation in each pixel cell has been described, where the driving electronics advantageously can be incorporated in a single active-matrix substrate layer (e.g. either glass or plastic) for each stack. The general electrochromic display advantages of high optical quality with respect to reflectivity, viewing angle, contrast and aperture being largely retained. The approach according to the present invention being advantageous in comparison to the prior art approach of stacking several electrochromic cells, each having their own active-matrix substrate layers, which makes such a prior art display quite thick, expensive and gives rise to severe parallax problems.

Thus, while there have been shown and described and pointed out fundamental novel features of the invention as applied to a preferred embodiment thereof, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated, and in their operation, may be made by those skilled in the art without departing from the spirit of the invention. For example, it is expressly intended that all combinations of those elements and/or method steps which perform substantially the same function in substantially the same way to achieve the same results are within the scope of the invention. Moreover, it should be recognized that structures and/or elements and/or method steps shown and/or described in connection with any disclosed form or embodiment of the invention may be incorporated in any other disclosed or described or suggested form or embodiment as a general matter of design choice. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.

CLAIMS:

1. A display device comprising a plurality of independently addressable pixels, wherein said pixels comprise: a first substrate; a counter-electrode; a second substrate; a stack of electrochromic-layers associated with said second substrate; an electrolyte disposed between said counter-electrode and said stack of electrochromic-layers; wherein said electrochromic-layers each are independently addressable for switching operation; and said electrochromic-layers are separated from each other by layers of an electrolyte.

2. The display device of claim 1, wherein an independently addressable working electrode is arranged between the second substrate and the electrochromic-layer adjacent to the second substrate in the stack of electrochromic-layers.

3. The display device of claim 1, wherein separate independently addressable working electrodes are associated with each respective electrochromic-layer in the stack of electrochromic-layers.

4. The display device of claim 1, wherein the electrolyte separating the electrochromic-layers from each other is a solid-state like electrolyte.

5. The display device of claim 4, wherein said solid-state like electrolyte is a polymer electrolyte.

6. The display device of claim 1, wherein said stack of electrochromic-layers comprises three monochromic electrochromic-layers.

7. The display device of claim 1, wherein the counter-electrodes of each pixel of the display device are connected to form one common counter-electrode.

8. A driving method for operating a pixel of a display device according to any one of claims 1 to 7, comprising the steps of:

providing at least one power line which is selectively connectable to an electrochromic-layer or to a working electrode associated with said electrochromic-layer;

selectively providing to said power line a bleaching or coloring voltage;

addressing the electrochromic-layer or the working electrode associated with said electrochromic-layer which is to be bleached or colored;

connecting said power line to said electrochromic-layer or said working electrode associated with said electrochromic-layer addressed;

retaining the connection of said power line to said electrochromic-layer or said working electrode associated with said electrochromic-layer addressed during a hold period;

disconnecting said power line from said electrochromic-layer or said working electrode associated with said electrochromic-layer addressed.

9. The method of claim 8, wherein:

addressing of the additional electrochromic-layers or the working electrodes associated with said additional electrochromic-layers is performed in a sequential manner in consecutive line periods.

10. The method of claim 8, wherein:

addressing of the additional electrochromic-layers or the working electrodes associated with said additional electrochromic-layers is performed in a parallel manner in the same line period.

EPO - DG 1

15. 08. 2002

41

ABSTRACT:

A display device comprising a plurality of independently addressable pixels (1) comprising: a first substrate (2); a counter-electrode (3); a second substrate (4); a stack of electrochromic-layers (5a, 5b, 5c) associated with said second substrate (4); an electrolyte (6) disposed between said counter-electrode (3) and said stack of electrochromic-layers (5a, 5b, 5c). Said electrochromic-layers (5a, 5b, 5c) are each independently addressable for switching operation; and separated from each other by layers of an electrolyte (7). A driving method for operating said pixel (1) comprises the steps of: providing at least one power line (8) which is selectively connectable to an electrochromic-layer (5) or a working electrode (10) associated with said electrochromic-layer (5); selectively providing to said power line (8) a bleaching or coloring voltage; addressing the electrochromic-layer (5) which is to be bleached or colored; connecting said power line (8) to said electrochromic-layer (5) addressed; retaining the connection of said power line (8) during a hold period; and disconnecting said power line (8).

(Fig. 1)

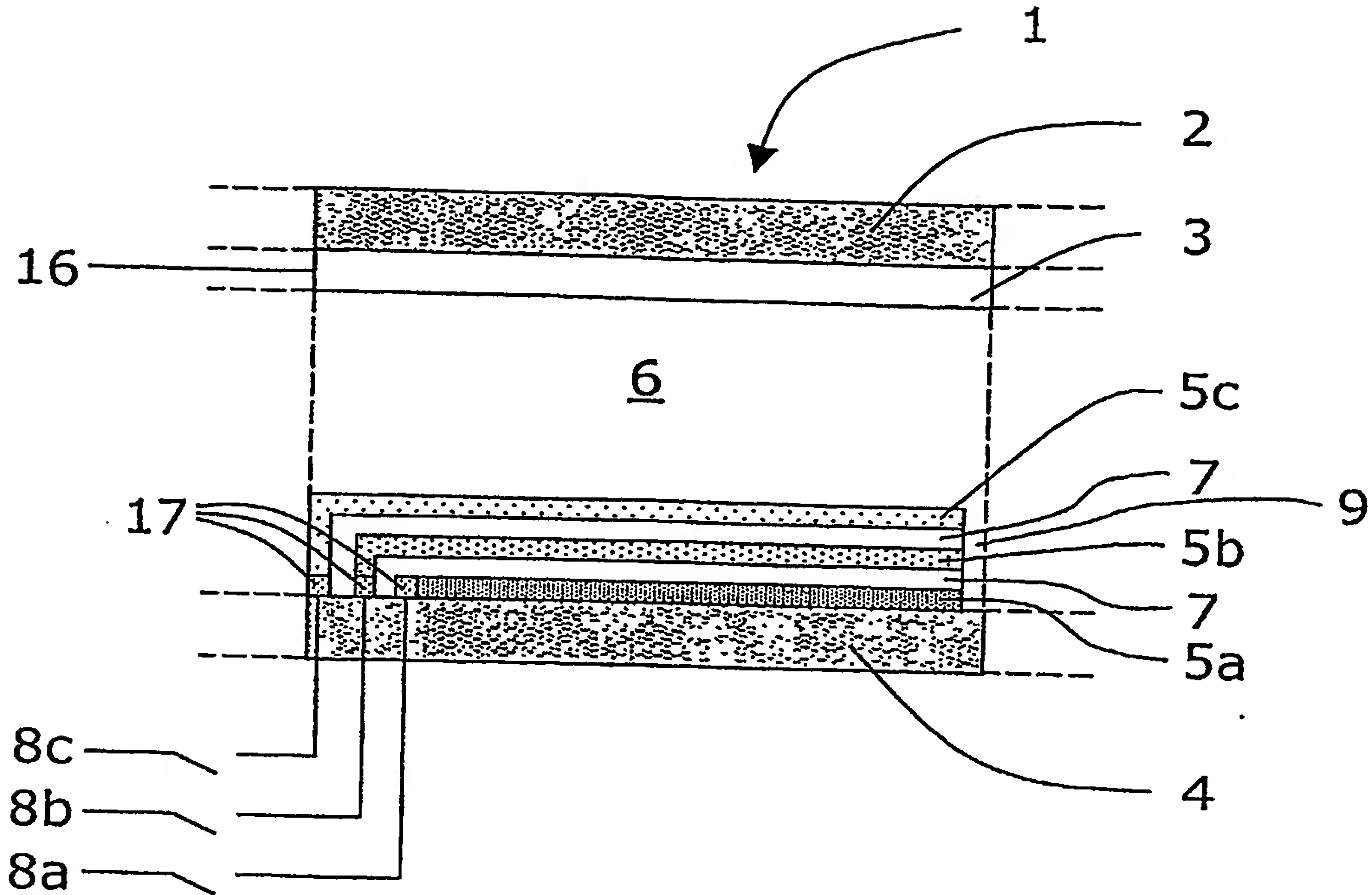
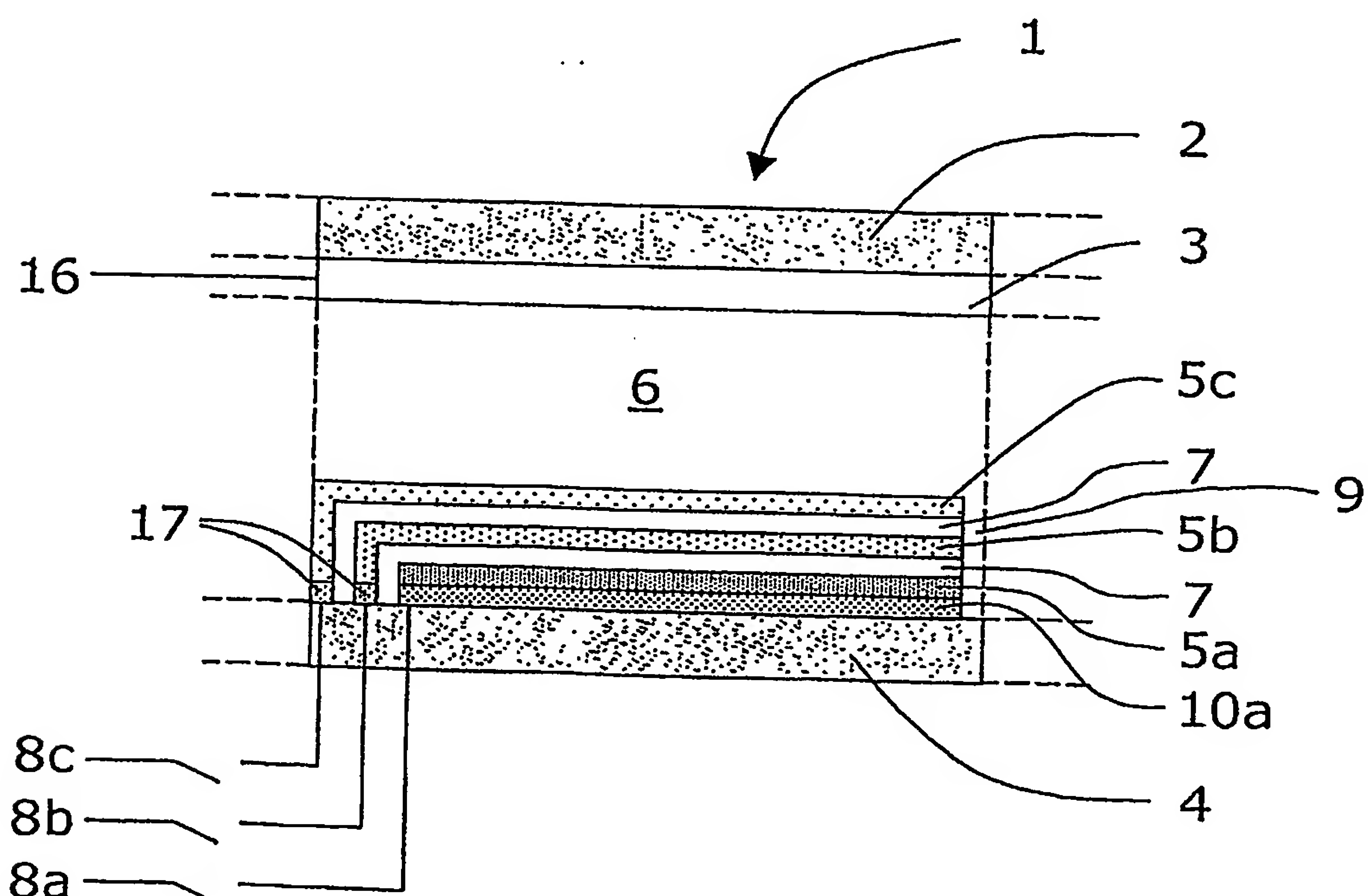

1
2
3
16
6
5c
7
9
5b
7
5a
17
4
8c
8b
8a

FIG.1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2
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5b
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8c
8b
8a

FIG.2

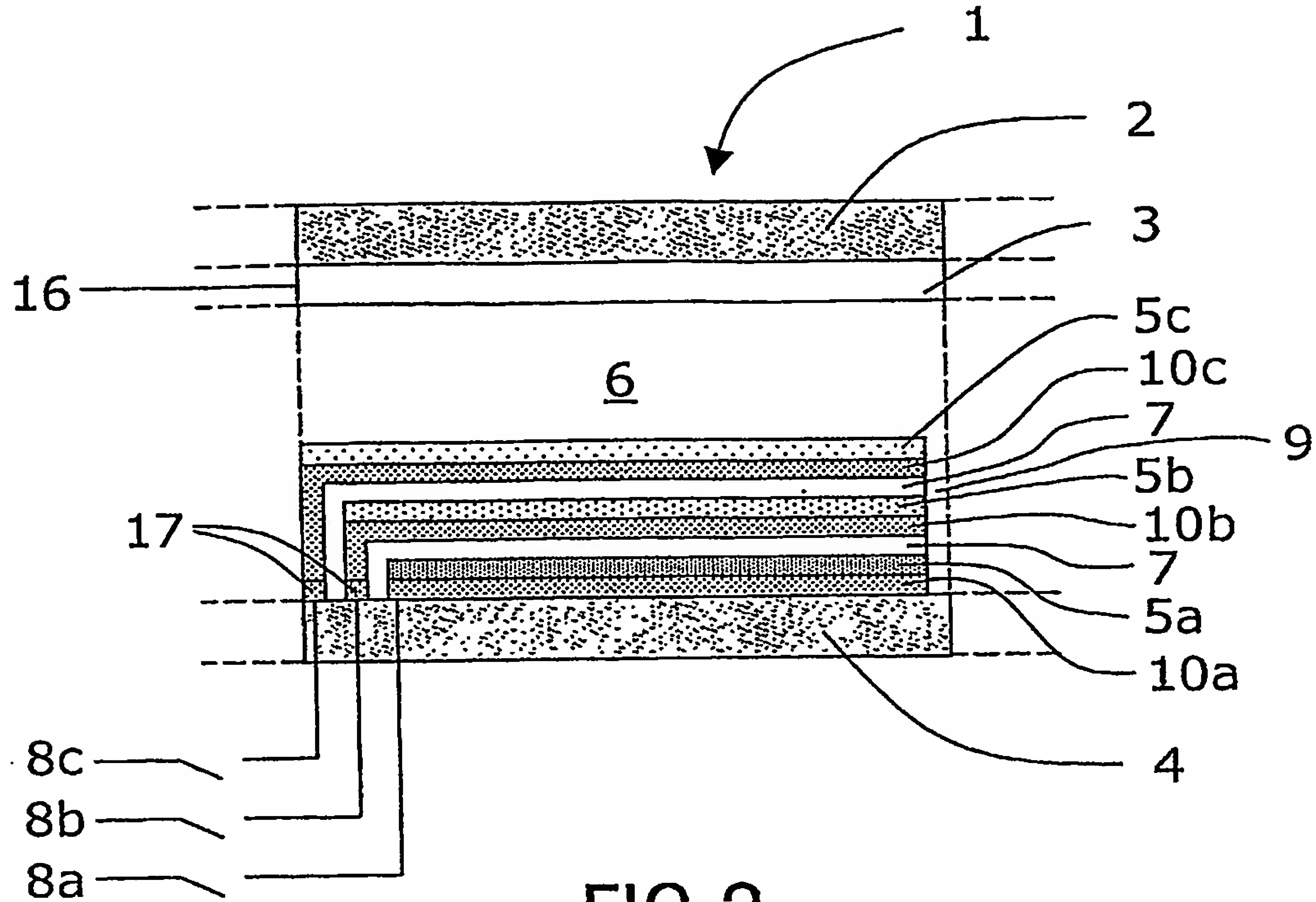


FIG.3

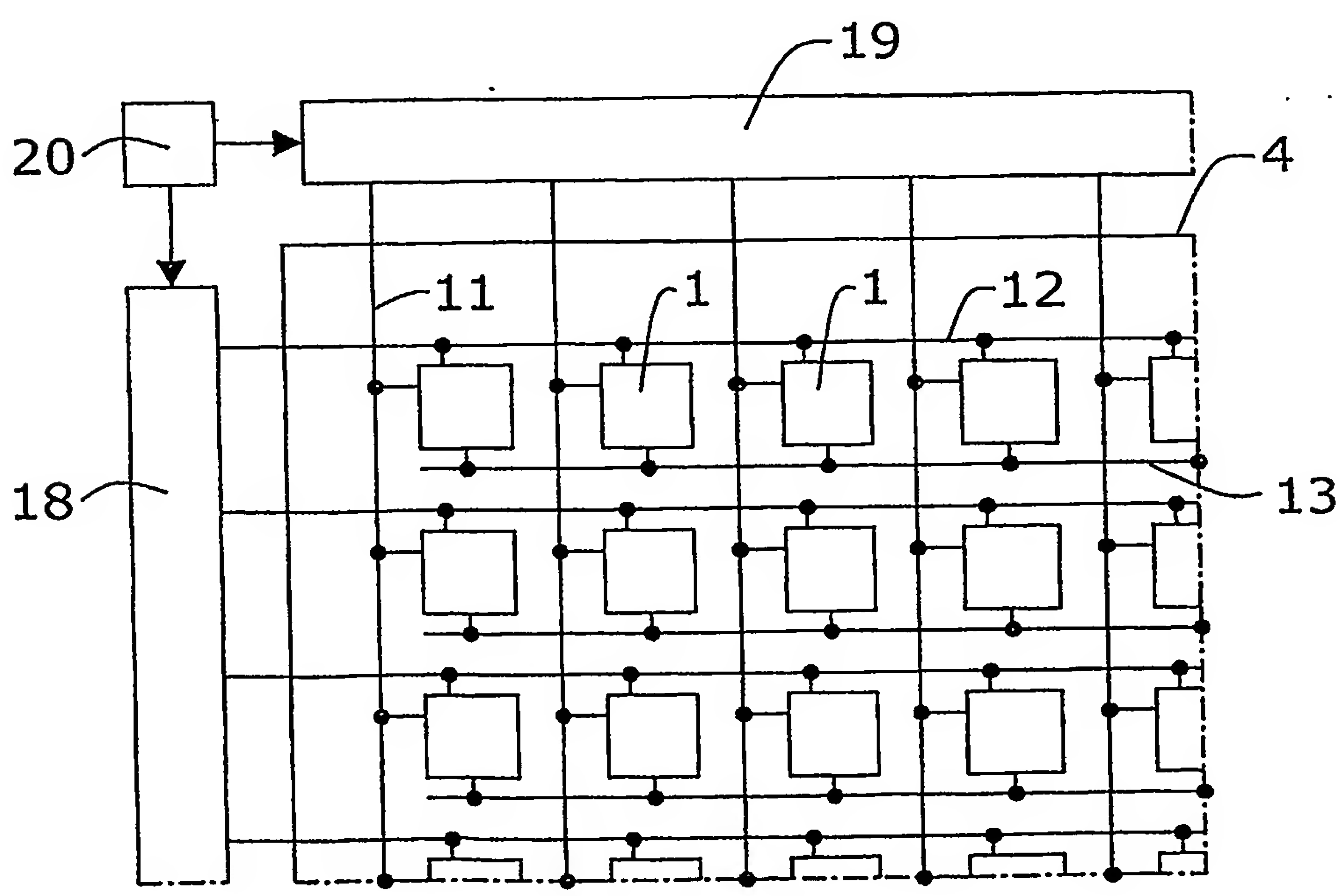
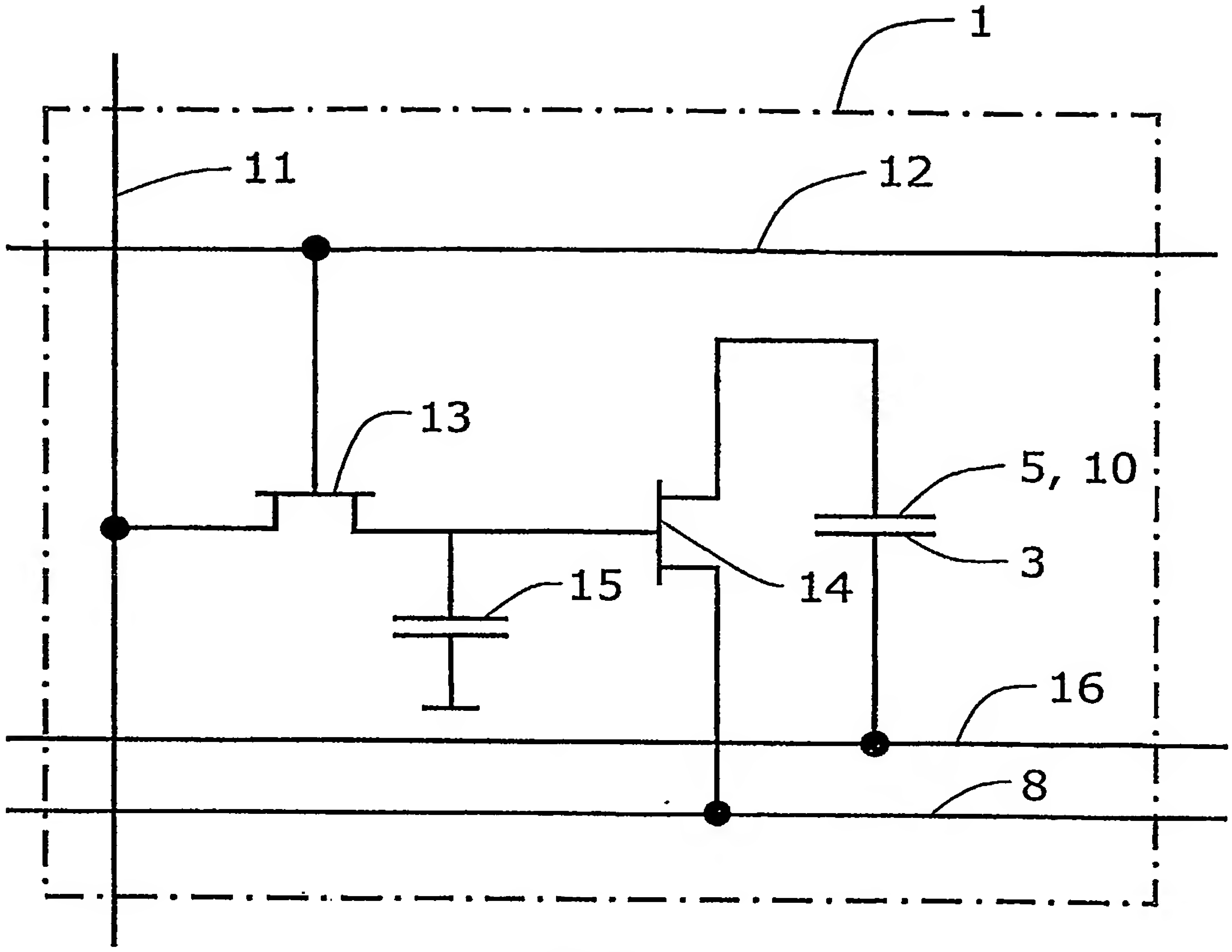


FIG.4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13
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3
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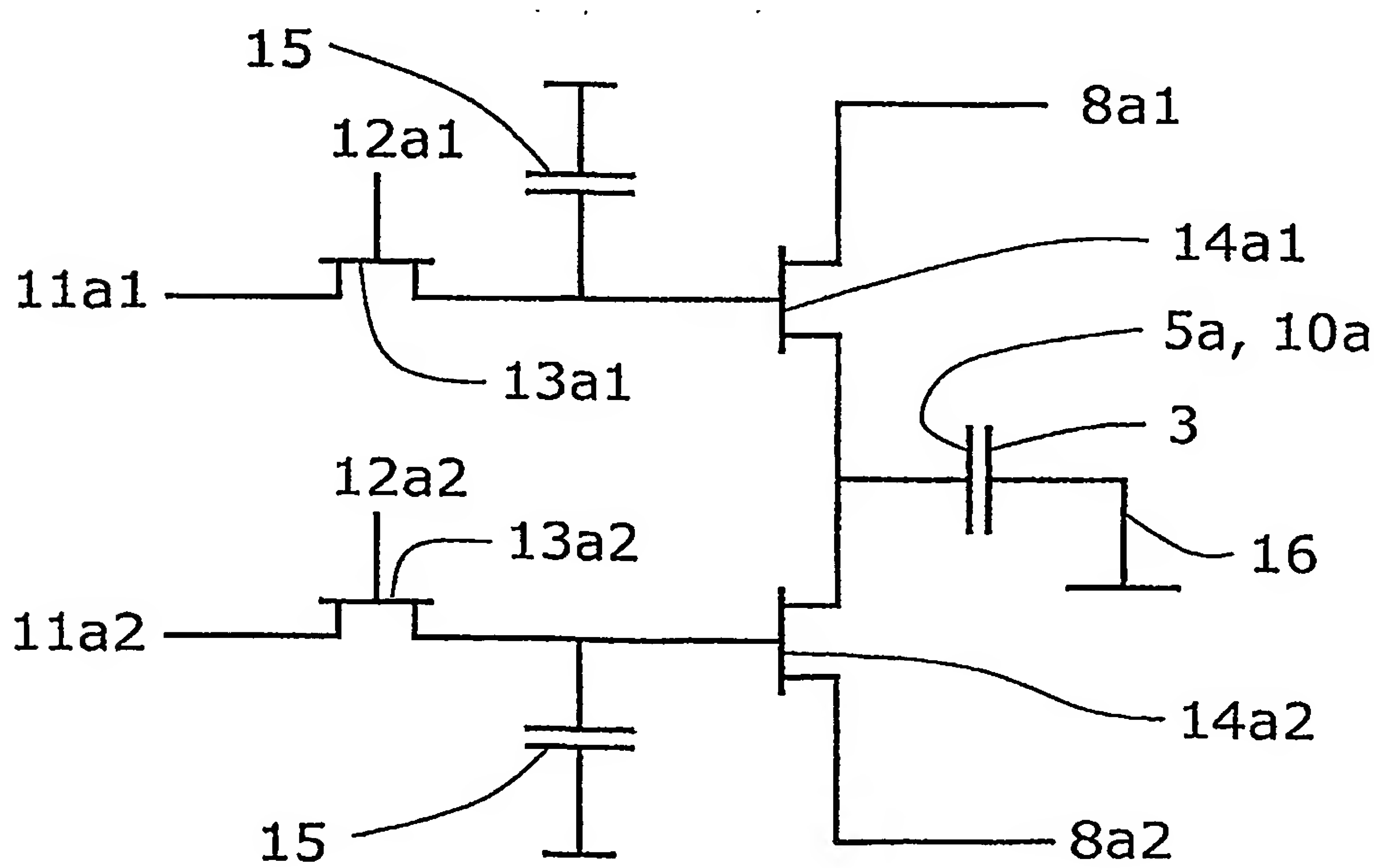
14
16
8

FIG.5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8a1
14a1
11a1
13a1
5a, 10a
3
12a2
13a2
16
11a2
14a2
15
8a2

FIG.6

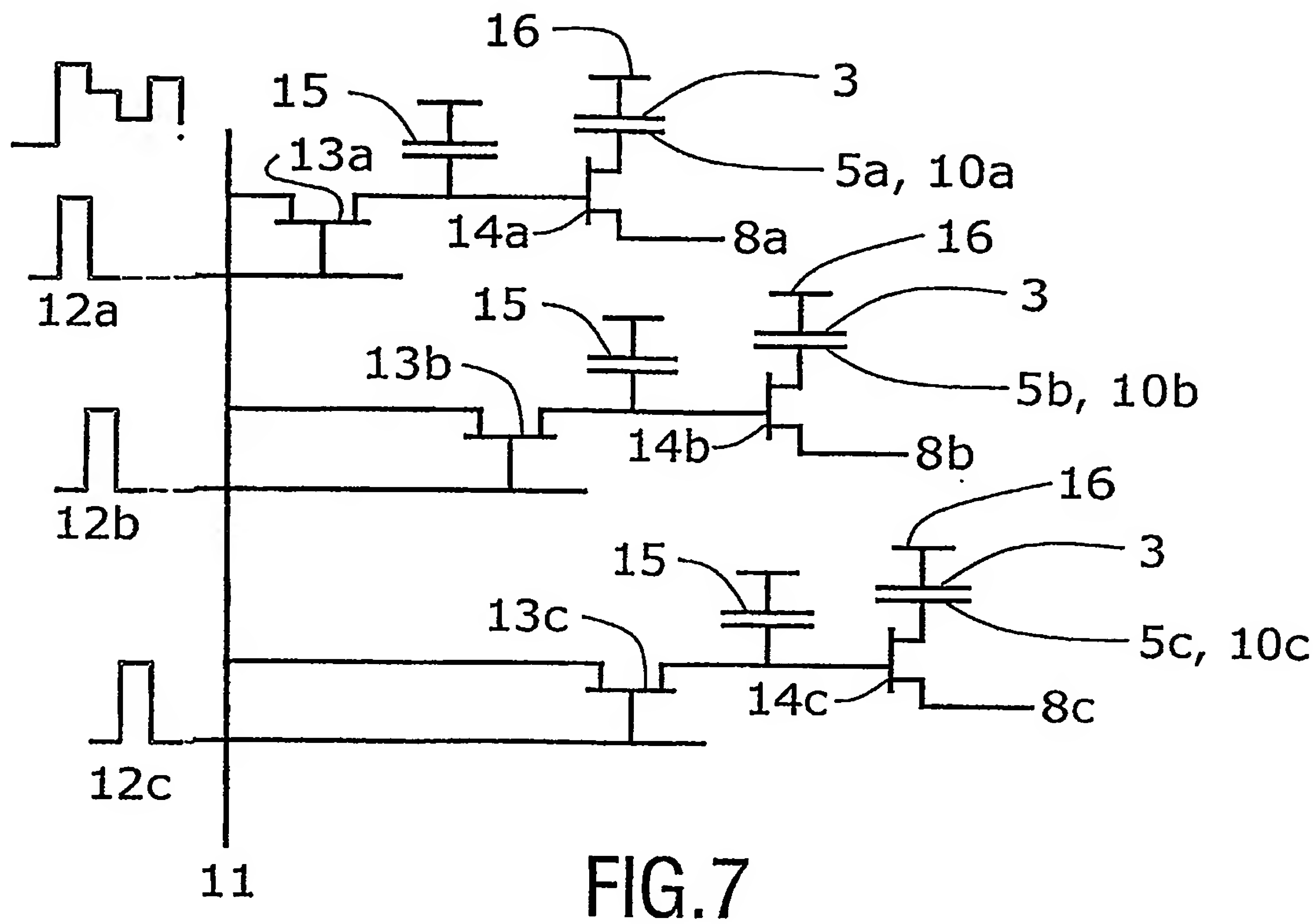
16
3
15
13a
5a, 10a
14a
8a
16
12a
15
3
13b
5b, 10b
14b
8b
16
12b
15
3
13c
5c, 10c
14c
8c
12c
11

FIG.7

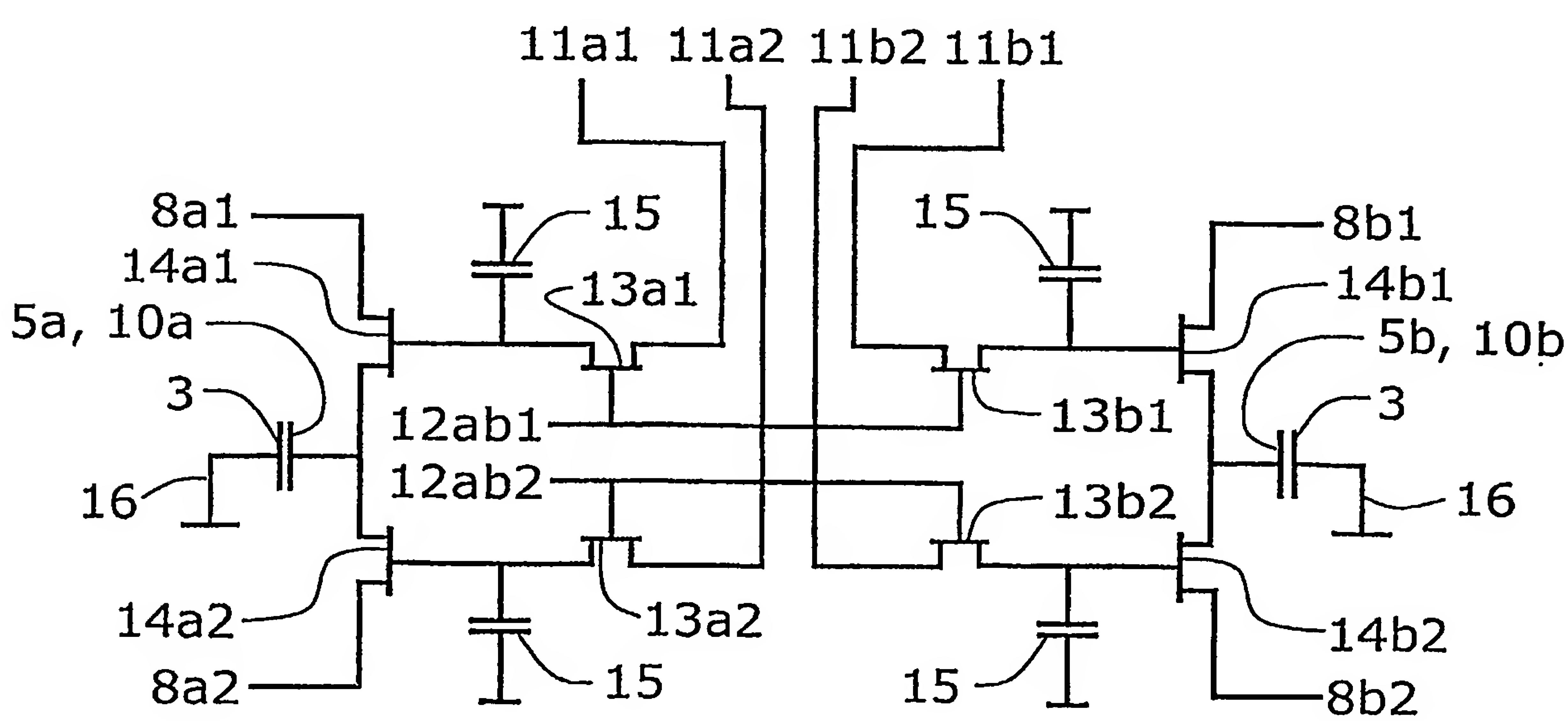
11a1 11a2 11b2 11b1
8a1
14a1
5a, 10a
3
16
15
13a1
12ab1
12ab2
14a2
8a2
13a2
15
15
8b1
14b1
5b, 10b
3
13b1
13b2
16
14b2
8b2
15

FIG.8